OBSERVATIONS

ON THE

MACULA LUTEA,

PART I.

OPHTHALMOSCOPIC APPEARANCES OF THE HEALTHY MACULA.

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OBSERVATIONS ON THE MACULA LUTEA.

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(*With 16 figures on the colored plates A–D.*)

A.—THE MACULA REFLEX.

OPHTHALMOSCOPIC APPEARANCES OF THE HEALTHY MACULA.

ACCORDING to the text-books and the references in the ophthalmological archives and journals, the macula lutea in the normal eye is generally represented as a patch of somewhat darker red than the surrounding fundus, containing in its centre the fovea centralis as a bright red spot.

In a few instances a narrow bright halo surrounding the macula region has been described and depicted. In all these pictures the halo (if shown at all) is represented as an oval with a long axis horizontal or slightly oblique (from 10°–15° to the horizon). All text-books state that it is difficult to see the macula at all, and some of those works which refer to the halo state that it can only be observed in children, and that only when the pupil is undilated by a mydriatic, under which condition, as above stated, it appears as an oval ring.

It is remarkable that, in spite of the most diligent search, I cannot find a single author in the whole range of ophthalmological literature who mentions the macula as appearing round when observed ophthalmoscopically. It is true Schmidt-Rimpler describes the macula, examined anatomically, in enucleated eyes, as being usually circular, but when

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referring to its ophthalmoscopic appearances, he describes it and its surrounding ring as a transversely placed oval (queroval), and thus he figures it in his well-known text book[1]; but he remarks, with his characteristic love of accuracy, that this appearance is not in harmony with his anatomical observations.[2]

The appearance of the macula floor and ring appears to have first been definitely laid down by Richard Liebreich in Graefe's *Archives* for the year 1858.[3] Since that time the description of the obliquely oval appearance of the macula ring has been repeated in words almost identical to those of Liebreich in every text-book on ophthalmology and physiology in which any description of it is given.

In addition to this, I notice that it is invariably stated that this ring round the macula can *never* be seen by the direct examination, *i. e.*, by the upright image,[4] and that, if it could be seen, the magnification is so great .that only a portion could come into view at one time; moreover, it is repeatedly affirmed that this ring can only be seen in dark children, and it is maintained that dilatation of the pupil with atropine causes it at once to disappear.[5]

On consulting the various atlases of the eye I find the pictures of the macula ring all having the same oval shape and axial direction, but beyond this they have few points in common. Thus Galezowski figures the typical macula region in his atlas as an oval ring brick-red in color, with a red fovea centralis on an orange-red base.[6]

Schmidt-Rimpler draws it as a canary-yellow oval, with an orange-centre on a walnut-brown base.[7]

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[1] See colored plate opposite page 321, 2d edition, 1888.

[2] Die Macula lutea anatomisch u. opthalmoscopisch, *A. f. O.*, xxi., 3, p. 17.

[3] Histologisch-ophthalmoscopische Notizen, *A. f. O.*, iv., 2, p. 301.

[4] "Auffallend ist es, dass der Lichtring im aufrechten Bilde fehlt."—Schmidt-Rimpler: "Handbook," p. 231. 2d ed.

See also *A. f. O.*, xxi., 3, p. 27.

Loring: *Transactions of the American Ophthalmological Society*, July, 1891, p. 29.

Mauthner: "Lectures on the Opthalmoscope."

[5] Panas: "Leçons sur les Rétinites," 1878, and Giraud-Teulon: "La Vision et ses Anomalies," p. 355, ed. 1881. Schmidt-Rimpler: *A. f. O.*, xxi., 3, p. 28, etc., etc.

[6] "Traité Inconographique d'Ophthalmoscopie," pl. 1, fig. 2.

[7] "Augenheilkunde," p. 321, 3d edition, 1888.

Panas and Mauthner both describe it as a brilliantly silvered ring.[1] Power speaks of it as "a soft whitish line," which he ascribes to the reflection of the rim of the mirror.[2] Landolt describes it as "a bright oval line, sometimes glistening with a red floor and intensely red, almost black, centre, the dark point in the centre being hardly ever absent."[3]

Helmholtz says: "The retina appears at the yellow spot much darker, of a grayish-yellow color, without any mixture of red,"[4]—a statement which Coecius says he cannot agree with. On the contrary, he says the floor of the macula is dim and of a much deeper red than the fundus generally; in some instances it is even brown or deep gray.[5] Schirmer poetically compares the ring (or Heiligenschein, as he calls it) to the small, finely branched, sparkling ice-flowers on a frosted window-pane.[6] Finally, Merkel[7] describes it as a citron-yellow patch with a round black spot in its centre, which corresponds to the fovea centralis.

By comparing the above description of the typical macula with its ring and centre, we find that no two writers agree as to the appearance and color.

As in many points my observations have led me to conclusions entirely different from those arrived at by the distinguished ophthalmologists above mentioned, I have ventured, though not without some hesitation, to lay the results before the readers of these ARCHIVES.

The conclusions which I have arrived at are:

I.—*That when observed in a certain way the macula ring in its entire circumference can be seen in every person under thirty-five years of age, and frequently, though with diminishing frequency, over that age.* The only cases in which I find an exception are in high myopes (*i. e.*, over 7 D or 8 D), in very fair people in whom the pigment is entirely or largely absent, and in cases in which the pigment is irregularly dis-

[1] "Leçons sur les Rétinitis," 1878.
[2] "Illustrations of the Principal Diseases of the Eye," p. 393.
[3] "Examination of the Eyes," p. 202.
[4] "Beschreibung eines Augenspiegels," p. 35.
[5] Criticism on the above.
[6] Ueber das oph. Bild der Macula lutea, *A. f. O.*, vol. x., Abth. 1, p. 149.
[7] Graefe-Saemisch "Handbuch," Bd. I., Th. 1, p. 34.

tributed and disturbed.[1] All such cases taken together do not nearly amount to five per cent. of the population. The observation of the macula ring is by no means easy in many cases, and it has necessitated repeated trials to determine the amount and direction of the light, and the direction and axis of the patient's eye, so as to produce the clearest image.

The reflection of light from the fundus is so strong that the feeble reflection of the macula ring is entirely overpowered, and no trace of it is to be seen. But I discovered that *if the source of illumination be gradually lowered, the reflection from the fundus decreases more rapidly than that from the margin of the macula, so that a time is arrived at when more light is reflected from the latter than from the general fundus, and at that moment the ring appears.*

There are cases in which the reflection from the macula circumference is so strong that no amount of reflection from the fundus can eclipse it; in such cases of course the ring may be observed by the full flame and even by the indirect method, but it is owing to the rarity of such cases that the appearance of the ring at all has become to be regarded as a phenomenon worthy of note. Moreover, in the direct observation the mirror should be held close to the pupil, in order to see the ring in its entirety, as otherwise the amount of the fundus seen at one time is too small to include it. In most cases, moreover, the macula ring can, even with reduced illumination, only be seen by placing the mirror and the patient's eye so as to observe the macula obliquely to the cone of reflected light proceeding from the macula itself, otherwise this cone of light produces so much dazzle and flare that the details cannot be clearly and satisfactorily made out.

In some cases in which at first no ring can be discerned, I have usually been able to see it quite clearly by moving the ophthalmoscope either laterally or vertically across the field, close to the cornea, until the retinal shadow just

[1] I have reason to believe the halo is often absent or at least less distinctly marked in so-called "neglected eyes," which have been disused from birth, but I have not yet been able to see a sufficient number of cases to state this definitely.

reaches the edge of the macula, when the whole ring instantly comes into view with great distinctness as soon as the illumination is sufficiently reduced. The cone of rays in undilated pupils can only be avoided by oblique observation by the direct method, which is to be preferred in every respect, and particularly because the magnification is not only greater than by the indirect, but, as Dr. Landolt first pointed out, it is invariably the same if certain conditions be observed.[1] He demonstrated that, provided the mirror with its correcting lens be held at the anterior principal focus of the patient's eye, the amplification of the image is exactly 20 diameters.[2] Now the anterior principal focus is situated 13.7 *mm* from the anterior surface of the cornea, a very convenient distance for observation. Moreover, if the correcting glass in the ophthalmoscope be at this distance, the magnification is dependent on the refraction of the patient's eye; whereas, with the indirect method, the magnification varies between wide limits (2 and 7 diameters) according to the focal length of the lens, the refraction of the patient's eye, and the position of the lens employed.

Lastly, it is especially important that the mirror used for the upright image should be of a suitable curvature to get the best result. With the indirect method it matters very little what focal length be used, owing to the interposed lens, but by the direct method it becomes a matter of considerable moment. In order to clear up this point practically, I had a series of concave mirrors made of focal lengths varying from 1.5 to 10 inches. I then, by means of cobbler's wax, stuck the mirror to be tested in its normal position in my ophthalmoscope, and made repeated trials with it, the wax holding sufficiently for observation but allowing of the mirrors being rapidly changed. In this way I found that the best average results at 14 *mm* distance were obtained with a mirror of $2\frac{1}{4}$ in. solar focus; mirrors of shorter focal

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[1] On the Enlargement of Ophthalmoscopic Images.—E. Landolt, *Brit. Med. Jour.*, March 1, 1880.

[2] Of course the correcting lens must be at the anterior focus of both the observer's and the patient's eyes that this should be mathematically correct, but if the observer has normal refraction he can hold his eye as close as he likes to the ophthalmoscope without any practical error.

length gave too diffuse an illumination; those over 3 in. began to show, as a rule, a distinct image of the flame, while those with a focus over 5 or 6 in. gave rise to flare rings and Heuse's phantom circles.[1]

Having thus arrived at the best practical focal length for the mirror, I got a series of them made of $2\frac{1}{4}$ inch focus, but with apertures varying from a pin's point to 4 *mm.* I found that very small apertures (under 2 *mm*) allowed too small a pencil of rays to reach the observer's eye, and thus the fundus appeared imperfectly illuminated, while apertures exceeding 3 *mm* caused a slight round shadow to fall on the fundus which increases in intensity with the size of the aperture. I found 2.25 *mm* and 2.5 *mm* to give the best results.

It is very necessary to remove all traces of reflection from the edges of the sight-holes and from the rims of the correcting lenses, which, though not always troublesome in ordinary fundus examination, may become so when observing the macula region, since the slightest reflection from the margin of the sight-hole, owing to its close approximation to the observer's eye, forms an indistinct but magnified image of itself in the shape of a semicircular flare or haze which occupies a considerable part of the usual field and greatly detracts from the clearness of the macula image.[2]

By observing, then, in the way above recommended, I find it best, as soon as I can see the macula at all, to turn down the gas flame rapidly to as low a point as possible consistent with good vision, and then the halo (or halos), if not previously seen, invariably (of course with the exceptions above named) come into view.

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[1] Ein Lichtreflex der Retina, *A. f. O.*, i., 1884, p. 155.

[2] Couper, in his "magazine" ophthalmoscope, by the invention of the chain-movement, by which a practically indefinite number of lenses can be rotated behind the aperture of the mirror without increasing the thickness or breadth of the instrument, has greatly facilitated the examination of the upright image; for Mr. Couper maintains (and I am quite of his opinion) that the *best* results can only be obtained by single lenses for each focal length, and not by the superposition of one lens on the other, as is the case in nearly all ophthalmoscopes in which the lenses are rotated by discs. For the examination of other parts of the fundus it does not matter so much which form be used, since the addition of two more reflecting surfaces will not interfere perceptibly with the clearness of the image, but in the examination of the macula it is essential that the number of reflecting surfaces should be reduced to a minimum, and for this reason alone the direct method is superior to the indirect one.

All the drawings accompanying this paper represent the ring as seen by the direct method, and therefore all appear circular. With the indirect method, however, I find it difficult to see the halo at all unless well pronounced, because the indirect method does not admit of the fundus being seen at all with the decreased illumination necessary to observe the halo with the direct method, the distance at which the mirror is held, together with the intervention of the lens, increases the reflection and renders the oblique observation of the macula extremely difficult.

In observing the halo by the direct method I find the use of atropine makes no difference, excepting to render the image clearer and more free from flare, and the only explanation that I can give why authors state that the use of atropine causes the ring to disappear, is that they have doubtless used the indirect method, by which the illumination is of necessity very great, and the reflection from the choroid considerably increased by the enlargement of the pupil, so much so as to mask the ring, which, as I have already stated, can only be seen by reducing the illumination in order to, so to say, darken the background. As, moreover, the intensity of illumination varies inversely as the square of linear magnification, the illumination by the indirect method must, *cæteris paribus*, be much greater than by the direct, and even that, as I have pointed out, is in most cases too strong when the usual amount of light is employed.

II.—*The macula is invariably circular, and probably corresponds to the extreme limit of the macular region.* When viewed by the direct method the ring always appears circular. If authors have until now seen the ring as an oval, as mentioned above, it is no doubt due to the use of the indirect method, and I find that in cases in which the ring is sufficiently intense to be seen by this method, it appears as horizontally or slightly obliquely oval.

Schmidt-Rimpler, in trying to account for the oval ophthalmoscopic appearance of what his anatomical observations showed to be a circle,[1] thinks it due to the fact that the curvature of the cornea is greater in the vertical than in

[1] Schmidt-Rimpler : *A. f. O.*, xxi., Abth. 3, p. 26.

the horizontal meridian, and consequently the circle appears horizontally oval. But the difference in curvature between the two meridians is obviously an insufficient explanation. The vast majority of persons possess a corneal astigmatism of less than 0.75 D, and the addition of a cylinder of this amount will only increase the apparent diameter of the ring by 0.14 *mm*, *i. e.*, less than its thirty-fourth part, an increase quite imperceptible. Moreover, if the curvature of the cornea were the cause, observation with the direct method should show the ring as a vertical oval, which is very rarely if ever the case. The explanation will, I think, be found in *the distortion produced by the lens and mirror*. If the light be placed at the side of the patient's face, the slight obliquity of the condensing lens is quite sufficient to distort the circle into a horizontal oval. In order to test this I selected a patient who had an unusually distinct ring, normal refraction, and less than 0.25 D of astigmatism, and atropinized his eye in order to avoid all error due to accommodation. On placing the light at the side of his face, when examining by the indirect method, I saw the horizontal oval ring. On directing the assistant to slowly move the light through a quarter circle to just above the patient's head, I noticed the macula ring change from a horizontal to a vertical oval and back again to a horizontal oval as the light was moved to a corresponding position on the other side of his face. Of course I had to tilt the lens in accordance with the shifting of the light, in order to bring the rays on to the macula, and it was this tilting of the lens which produced the change in the shape of the macula ring. Had the ring been a definite structural mark on the retina or choroid and not a mere reflex, it would of course have remained unaltered, but the fact that the ring is due to a reflection allows a slight amount of shifting, and it is this slight movement which causes the ring to appear drawn out into an oval, so to speak, when the light is at the side of the patient's face and the lens and mirror are imperceptibly tilted in consequence.

When the direct method is used the distortion (due to the tilting of the lens) is avoided and the ring appears circular.

All the microscopical and entoptical observations, as far as I have been able to find, show that the macula is circular. Schmidt-Rimpler, as above stated, draws special attention to the circular form of the macula in his anatomical preparations.

Meyerhausen,[1] Ewald,[2] and others have frequently figured and described Clerk Maxwell's entoptic figure as a bluish, star-shaped, circular patch.

Lastly, Purkinje's candle experiment shows the macula to be quite circular.

As this experiment helps us to become better acquainted with the shape of the macula than any other I know of, and as I am not aware that the detailed description of the appearance of the macula by this method has ever been given, I trust it will not be deemed out of place to describe it here.[3]

By moving the candle up and down or sideways about 10° to the outer side of the visual axis, while gazing at a black surface in a dark room, the following points may be noticed by a practised observer.

First, the retinal vessels appear raised and of a chocolate color on a dull gray-brown background. Suddenly, in the axis of vision, the macula comes into view as a brilliant, dark brick-red, *perfectly circular* patch, standing alone on the background. The edge of the macula appears raised, casting a shadow into its cup-shaped interior, as the candle is moved. On the edge of the macula nearest to the candle (*i. e.*, the inner side) a brightish reflex may be seen, reminding one of the ophthalmoscopic macula reflex, excepting that it only occupies a portion of the circle at a time—*i. e.*, the part directed to the light. Of course, this bright reflex may be seen to travel round the edge of the macula if the light is made to revolve in a circle round the optic axis. The macula appears about half the diameter of that seen by

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[1] *A. f. O.*, vol. xxvii., p. 2.

[2] "Researches Heidelberg Institute," vol. ii., 2, p. 241.

[3] A detailed description of these experiments, with an exeellent drawing, was published in 1882 in these ARCHIVES, vol. xi., p. 476, etc., by Wm. C. Ayres, under the title, "The Blood Circulation in the Region of the Yellow Spot."

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the direct method with the ophthalmoscope. The macula region appears quite homogeneous and free from vessels except at its margin, where they curl over and are lost to view. Frequently the vessels are seen to divide dichotomously just before reaching the macula.

It takes some moments before the other eye, when experimented on after being closed, can perceive the vessels; moreover, the macula does not appear red for some moments, but its redness soon becomes markedly in contrast with the rest of the dull-brown ground.

When examining the macula ring with the ophthalmoscope, I invariably see the retinal vessels curling over the ring into the macula depression, exactly corresponding to what I see in Purkinje's experiment mentioned above. These vessels pass into the macula in children as well as in adults,[1] and frequently divide dichotomously just over the ring, becoming rapidly so fine that they can no longer be traced any farther. I have only met with two cases in healthy eyes in which I could trace a retinal vessel up to the fovea itself. One was in a native boy from the Upper Congo (Fig. 11), who had marvellously acute vision, and in whom I could trace two minute arterial twigs right up to the fovea centralis. The other was in a patient with a healthy fundus and normal refraction and vision.

As the raised edge of the macula seen by Purkinje's method occurs just inside the point where the vessels divide dichotomously, and as it is just there that I see the ring with the ophthalmoscope, I have reason to believe that the ring corresponds to the extreme limit of the macula region. This view has been further confirmed by some experiments I have made, and which, when completed, I hope to be able to describe in a future number.

III.—*The ring is no doubt due to the cup-shaped dip of the macula.* It has been generally recognized that the surface of the retina presents a depression at the macula, commencing at its circumference and increasing rapidly towards the fovea, where the dip is often very considerable; so much so,

[1] See Leber's reply to Johannides, Graefe's *A. f. O.*, vol. xxvi., Abth. 2, p. 127.

that the older writers considered it as a foramen. Max Schultze described it minutely and figured it in his two celebrated diagrams, which have been copied all the world over. Although it is quite impossible to recognize any alteration in level of the macula with the ordinary ophthalmoscope, there are many other ways of assuring one's self of this fact. The most obvious method that suggests itself, is to make axial sections through the macula region of a removed eye with a razor, and to examine the cut surface under a low power. But there are many difficulties in the way. It is exceedingly difficult to get perfectly fresh and healthy human retinæ, and, when obtained, they must be examined immediately, as degeneration of the retinal elements sets in very rapidly, and especially where it is most to be avoided, viz., at the macula. If the eye be opened and thrown into water, the cells rapidly imbibe the fluid, and swell up, so that any attempt to ascertain the difference in level is seen at once to be hopeless. After some time the surface of the retina gets sodden and raised in the form of minute papillæ, an appearance which becomes very striking round the macula if examined with a low magnifier. It is exceedingly difficult to prevent the retina becoming detached when manipulated after removal. The only way to accomplish this with certainty is to freeze the eye immediately it is excised, and then to make the section behind the equator, and afterwards through the macula itself. The vitreous need only be slightly frozen. The position of the macula is much more readily found by marking the top of the eye before removal, by which its exact position can be determined.

I have experimented with Giraud-Teulon's binocular ophthalmoscope, which has shown to me very clearly the alteration in the level of the vessels as they curl over the edge of the macula.

I think Purkinje's candle phantom, as described above, gives a very reliable and good representation of the cupping of the macula, as the relative depth and slope of various parts of the circumference can be judged by the length and blackness of the shadow cast by its side, but unfortunately one's observations are confined to one's own eyes.

Many years ago, Loring made some interesting experiments to ascertain whether the reflex ring could be produced artificially.[1] He made a small hole in a piece of smooth tinfoil (the $\frac{1}{8400}''$ in thickness), which he squeezed over a disc of plain glass and carefully squeezed a second piece of foil over the first, thus making a uniformly smooth surface with a circular depression of less than the $\frac{1}{8400}$ of an inch in depth.[2] This, being placed in the plane of the posterior pole in an artificial eye, showed a glittering ring with the ophthalmoscope very similar to that seen in the human eye. I have made similar experiments myself both with goldbeater's-skin and with tinfoil, and obtained identical results with those of Loring, nor can I see how they could be otherwisė. It therefore occurred to me that the retinal arteries might produce a reflex in the same way by slightly raising the level of the tissue above them. I therefore cut a hair from the head into short pieces and laid them on a cover-slip moistened with equal parts of egg albumen and glycerine. This I dried slightly over a flame and squeezed a piece of tinfoil over the top. The minute ridges thus produced formed the best substitute I could make for the retinal arterioles. On measuring the height of the ridges I found them to vary between the $\frac{1}{1500}$ of an inch and the $\frac{1}{3000}$ of an inch. I then placed it at the retinal plane of my artificial eye (Landolt's) and examined it with the ophthalmoscope. The ridges gave all the appearance of the glistening sheen which one observes playing over the arteries. So far the analogy appeared to hold good, but it fails to explain the reason why this shot-silk sheen disappears with age, unless it is that in later years the surface of the retina reflects less light.[3]

IV.—*I observe three forms of rings.* Of these the most common is a bright scintillating reflex resembling shot-silk

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[1] *Transactions of the American Ophthalmological Society*, July, 1871, p. 77.

[2] Dr. Loring does not say how he arrives at his figures, but I have repeated his experiments most carefully, and I find his figures are much too high. I never found the difference in level less than $\frac{1}{3000}$ of an inch (0.0125 *mm*), nor can I discover where tinfoil so thin as the $\frac{1}{8400}$ of an inch (0.003 *mm*) is to be obtained.

[3] Brecht, *A. f. O.*, xxi., Abth. 2, p. 1, describes a similar experiment to that of Loring, and gives a colored diagram of the ring he saw in the artificial eye.

similar in appearance to that noticed skirting the blood-vessels and over the greater part of the fundus in darkly pigmented eyes (Figs. 2, 4, 9, 11, and 12). In some cases it only exists as a circle round the macula, rapidly fading away and losing itself as it reaches the floor, but spreading out for some considerable distance on the farther side of the macula, the distance varying to some extent with the position of the mirror, so that the breadth of the ring cannot be even approximately measured, although the inner margin is much more sharply defined, and varies within very narrow limits, as the mirror is moved or tilted. This form of ring can usually only be seen when the gas is turned down as low as is consistent with good vision. In such cases, if the ring is well marked, the shot-silk appearance will appear following the vessels, now over them, and now as silvery flames extending here and there along their sides, appearing and disappearing in various places as the mirror is shifted and tilted. The distinctness of this shot-silk sheen is always very marked in dark eyes, becoming less evident as the pigment decreases, until in very fair eyes, in which the choroidal vessels begin to shine through, it is hardly visible, although with patience and careful adjustment of the position and amount of the light traces of it can generally be seen. But still it is worthy of note that the macula circle is always the last to disappear, and the fundus must have very little pigment indeed if it cannot be made out at all.

I believe that this ring is partly due to a reflection from the fibres of Müller, where they expand into the membrana limitans interna, but this cannot be the only cause, as the reflex along the sides and over the vessels is always more conspicuous than anywhere else, and I can offer as an hypothesis that the fibrous sheaths of the vessels contribute largely to the cause, by slightly raising the portions of the retina immediately overlying them.

The sheen is nearly absent in the immediate vicinity of the disc, and is entirely absent inside the macula region, excepting a narrow variable band just within its boundary. I searched carefully for this reflex within the macula in the case of the Congo boy, in whom I traced the retinal vessels

to the fovea itself, but did not observe any sheen along them, although abundantly present along the vessels elsewhere, and even along the smallest twigs. Whether the slope of the macula floor or the scanty development of Müller's fibres at this point was the reason for the absence of reflex, I will not venture to surmise.

The second form consists of a radiating ring of a grayish-white lustre round the macula (Figs. 2 and 3). The radii are all directed towards the fovea; although losing their outline at the edge of the macula, they may be traced for a variable distance (usually about $\frac{1}{2}$ PD) away from the macula. At the same time the fibres may be traced radiating for some considerable distance from the margin of the disc. They bear a striking resemblance to nerve fibres, and I am of opinion that they are due to their partial translucency, although I am aware that Professor Schweigger, who has given great attention to this subject, considers the similar appearance round the disc due to a peculiar arrangement of the connective-tissue fibres and not to the nerve fibres. To test this I compared several of these cases side by side with cases of undoubted opaque nerve fibres, and fortunately I found a patient in whom varying degrees of opacity of the nerve sheaths were present, and in parts where the fibres were merely translucent the appearance was identical with the striæ above mentioned.

The third form is so conspicuous that it may be seen even with the brightest illumination as a well marked whitish or golden ring of metallic lustre of the well known oval shape when examined with the inverted image, but quite circular with the direct method (Figs. 1 and 12). It is much narrower than the other two, and is sharply limited just inside the macula circumference, and becoming rapidly lost on its outside.

In these cases, which occur for the most part in children, the macula can be seen to be raised or to have a thickened border, and I think that the shape of the macula border is the cause of its prominence.

In the foregoing pages I have stated:

That the ring around the macula can always, with a few

exceptions, be seen in persons under thirty-five years, and with diminishing frequency in older subjects.

That the macula ring is invariably circular and probably corresponds to the extreme limit of the macula region.

That the ring is undoubtedly due to the cup-shaped dip of the macula region; and that I observe three distinct forms of macula rings; and I have also tried to account for these various appearances.

I would now like to add some further conclusions which my observations and experiments have led me to consider probable.

One reason why the ring is most marked in children (so much so, in fact, that it can frequently be observed with full illumination and by the indirect method) seems to be that in early age the circumference of the macula is formed by a rounded ridge which stands above the general level of the retina. I have been led to this conclusion by the examination of the eye of a youth, which I excised for a deep corneal wound a few weeks ago, and in which I could distinctly see the ridge with the naked eye immediately after excision, and before I placed the divided bulb in a preserving fluid. Inside this ridge the retina sloped more or less gradually towards the fovea. An ophthalmoscopic examination of the remaining eye showed a reflex ring of the third form above described.

I have reason to believe that as a person advances in years this ridge flattens down, but whether the general slope of the macula becomes actually less or not, I cannot say. One thing is certain—the shot-silk reflection of the retina is most conspicuous in childhood. It appears to become less and less with advancing years, and towards middle life it insensibly disappears, and with it the reflection of the macula ring.

I must still point out that occasionally another ring inside of the macula may be observed, which seems to correspond to some further change of level in the floor of the macula between the edge of the macula region and the fovea centralis (see Fig. 1).

Seeing the ring in almost every person, and being thereby able

to determine the limit of the macula region, it may prove of practical value in diagnosing whether a lesion or defect is situated within or without the region of acute vision.

B.—THE FOVEAL REFLEX.

At the centre of the macula ring a very small ring is frequently seen at the edge of the dip of the fovea centralis.

As regards this ring, from anatomical considerations alone, I think no other conclusion is possible than that it is due entirely to a reflection from the edge of the fovea; and I have not the slightest doubt that all the other kinds of reflexes to be met with at the fovea are due to the direction and shape of the sloping sides of the pit. The foveal reflex assumes a large number of shapes. It is generally very bright, like burnished gold, being sometimes a minute but perfect circle (Fig. 9), but more often shaped like a "C" (Fig. 6), the gap in the circle moving with the mirror and position of the light. Occasionally one sees a central spot of reflection (Fig. 4) which varies in different eyes, from a mere point of light to a long flare spot or comet (Figs. 7 and 8), with the apex at the fovea and the base of the "tail" at or near the circumference of the macula. This flare spot is very striking and very characteristic, but it is undoubtedly due to the same cause as the foveal ring, since I have traced every stage of its development.

We see it in its simplest form as a spot of light (Fig. 4), then as a small ring (Fig. 5), then again as a series of dots (Fig. 3), then a horse-shoe form or a portion of a ring (Fig. 6). This in other cases appears with its centre filled and spread out like a bat's-wing or fish-tail gas-jet (Fig. 13). In other cases again it looks like a short comet (Fig. 7), and sometimes as a long comet with a tail extending as far as the edge of the macula (Fig. 8). I have even seen it appear as a glistening horizontal line reaching from a central bright dot to the limit of the macula. These are some of the forms which occur, but the appearance of the foveal reflex is exceedingly varied. The foveal reflex, like that round

the macula, becomes less visible with age and beyond middle life often disappears altogether, but it may frequently be seen as a tiny bright speck in the centre of the slightly darker red background when all traces of the macula ring have vanished.

Several authors, especially Helmholtz, Loring, and Brecht, point to the similarity between these reflexes and the appearance of the depression seen in the tympanic membrane below the end of the handle of the malleus.

I may still refer to the fact that I find some authors in doubt as to the fovea reflex being always in the centre of the macula ring (being placed by many a little above the centre). My observations invariably show the foveal reflex to be at the centre, when in the shape of a ring or a dot, and in other shapes the apex of the reflex is always at the centre likewise. If it does not appear in the centre it is due to the fact that the fovea being a deep depression, the reflex remains stationary, whilst the macula ring can by the tilting of the mirror or lens be made to move within narrow limits, and thus be made apparently to cause the fovea to appear eccentric.

I have stated above that the fovea reflex seems unquestionably due to the reflection of the edge of the fovea, and I fully believe that the varying appearances can all be accounted for by the fact that the foveal pit varies in shape as Schmidt-Rimpler and others have shown.

C.—THE COLOR OF THE MACULA.

I do not think it will be necessary to say a great deal on this head, as it is difficult to amplify with words that which has been so carefully depicted in the accompanying drawings. I would, however, remark that I do not observe any noticeable change in the color of the macula when varying the degree of illumination. I have taken great pains to get the color to appear right when seen by daylight, although as the drawings were made by gaslight the color is more correct when seen under the same conditions.

In many cases, especially in persons over thirty-five, there

is very little difference in color between the macula and the rest of the fundus, and I find the same holds good in high myopes.

I believe that it may be taken as a general rule that in normal eyes of Europeans the inner portion of the macula appears of a more intense or brighter red than the fundus generally, the color deepening as it approaches the fovea centralis, where it is almost always masked by the bright foveal reflex varying in shape and intensity.

Of course exceptions do occur, and the intensity of the red varies considerably in different individuals, there being naturally an ascending scale from very fair to very dark-haired people. I have never met with a black or brown appearance of the fovea centralis, such as has been depicted by several writers as mentioned in the introduction, although on one or two occasions I have seen a deep shadow which was no doubt due to the foveal pit being unusually deep and narrow, and which has given rise to the mistaken idea of a black or dark-colored fovea centralis.

I have noticed that the macula region is devoid of that faintly granular appearance which can almost invariably be seen over the rest of the fundus by carefully focussing with the direct method of observation.

I have frequently observed in the macula area, and especially near the fovea, one or more minute yellowish dots somewhat resembling fatty particles; in some cases they appear dull, in others glistening. I am not sure whether they ought to be considered as pathological or not. At any rate they are exceedingly common in the macula area, though they are by no means confined to that region.

In concluding this article I am fully aware that I have by no means exhausted the subject, and that it will no doubt be possible to find exceptions to the rules I have tried to establish. But I cannot help feeling impressed with the importance, not to say the necessity, of arriving at such a definition of the ophthalmoscopic appearances of the healthy macula as will enable us to distinguish the slightest trace of a pathological condition in this the most essential portion of the retina.

Explanation of the Colored Drawings.

All the drawings represent the macula in perfectly healthy eyes, and comprise characteristic and carefully selected specimens of the chief varieties which have come under my notice.

FIG. 1.—Shows a very well marked macula ring, with a foveal, and also an intermediate or secondary ring. The macula ring is characteristic of the third type as mentioned in the text.

From an English youth, æt. eleven, with brown irides. H = 2 D. V = $\frac{6}{6}$.

FIG. 2.—A good example of the first or ordinary type of macula rings (*vide* text). The fovea appears a dull red circular spot. Five glistening "crick" dots surround it. They appear like polished specks of metal, but the lustre can naturally not be rendered in the drawing. The floor of the macula was very little darker than the surrounding fundus. From an English youth, æt. 18. V = $\frac{6}{9}$; Em.

FIG. 3.—A macula halo of an intermediate form between the two described above. The foveal ring presents a peculiar circle of small yellowish dots arranged with great regularity. From an English boy, æt. eleven. H = 1 D. V = $\frac{6}{6}$.

FIG. 4.—A common form of macula halo. This halo is peculiar in that it occupies nearly the entire macula region. The fovea appears as a small yellow spot. From an Englishman, æt. twenty-five, V = $\frac{6}{5}$; Em.

FIG. 5.—Shows a characteristic fovea often seen in adults. It is quite round and of a buff color like a fat-cell. The macula ring was barely visible, but consisted of a number of faint radiating lines which can be traced nearly to the fovea. From a man, æt. twenty-seven, light-brown hair. V = $\frac{6}{6}$; Em.

FIG. 6.—A characteristic horseshoe form of the foveal reflex. The gap in the small circle can be made to assume almost any position by varying the position of the mirror and light. This macula reflex is an example of the second class. From an English boy, æt. eighteen. V = $\frac{6}{6}$; Em.

FIG. 7.—Exhibits a short "comet flare" with the apex at the fovea. The macula region is not homogeneous, but the arrangement of the pigment layer in lighter and darker spaces shows a radiating appearance, the light streaks tending towards the fovea. From an English girl, æt. eighteen. V = $\frac{6}{6}$. H = 1 D.

FIG. 8.—A long "comet flare," from a boy with light flaxen hair, æt. eight. V = $\frac{6}{6}$; Em. The direction of the tail is towards

a point just above the disc. *I have found that comets are invariably either in this direction (or more rarely) directly inwards.* The sight in this and the foregoing case was perfect, and the eye in the latter emmetropic. This is noteworthy, as these "comet flares" are supposed by Marcus Gunn to be confined to amblyopic myopes. (*Trans. Oph. Soc.*, vol. viii., p. 173.)

FIG. 9.—A very pronounced example of the 1st class of macula rings. The foveal ring is quite circular,—the fovea itself being bright scarlet. From a very dark-olive-complexioned Spanish girl with black hair and dark-brown irides. $V = \frac{6}{6}$. $H = 1$ D.

FIG. 10.—The macula of a Siamese boy, æt. twelve, born in India. The radiating macula ring of class 2 can be faintly discerned. The floor of the macula is dark, which makes the fovea look redder by comparison than it actually is. The boy had a dark-yellow complexion with dark-brown irides and brown-black hair. $V = \frac{6}{6}$. $H = 1$ D.

FIG. 11.—The macula region of a native African boy, æt. sixteen, of the flat-nosed prognathous negro type, from Vidi, Lower Congo region. The reflex from the whole fundus is very pronounced, but the general color of the fundus, as indeed in all the natives of Equatorial Africa, is much lighter than in the case of half-casts from the same region, of American and West Indian negroes, and even gypsies. Two distinct macula halos, one lying over the other, can be made out quite clearly.. Both halos are quite circular, the superficial one extending further over the floor of the macula than the deeper one. By shifting the mirror the superficial one could be seen to glide slightly over the deeper, thus showing that they were due to different causes and to different layers in the retina.

Two retinal vessels, one arterial and one venous, could be traced to the fovea, which appeared as a dark cherry-red circular patch. Three bright crick dots are to be seen on its upper border. The two yellowish streaks, beneath the horizontal superior temporal artery, are due to a ruptured choroid of long standing from a severe blow in the eye, but this in no way affected his vision, which is quite phenomenal, the eye being absolutely healthy. $V = \frac{6}{1.5}$ and $J = 1$ at 6 feet. H (manifest) $= 0.75$ D.

FIG. 12.—The macula region of a native boy from Stanley Pool, Equatorial Africa. This boy belongs to a distinct and superior race to the former, having a well developed nose, and thinner, less prominent lips. The general reflex along the

blood-vessels of the fundus is less marked than in the former case, but the macula ring is very prominent, and appears to be distinctly raised above the general level. Quite a number of small twigs from the superior and inferior temporal arteries pass under the ring to disappear on the floor of the macula after bifurcation.

The fovea is reddish, with a bright round central reflex spot. His vision exceeded anything I have ever noticed before or since. V = $\frac{6}{\frac{6}{12}}$ and J = $\frac{2}{3}$ at 6 feet. H (manifest) = 0.75 D. Astigmatism nil.

FIG. 13.—The macula region of a negro from the Barbadoes, æt. thirty.

The color of the fundus is several shades darker than that of the Congo natives. The macula ring is very feeble; it is only seen as a faint shimmer, after the gas had been lowered. The macula region is darker towards the fovea. The foveal reflex is somewhat in the shape of a bat's-wing burner, being brightest at the centre of the fovea. V = $\frac{6}{6}$; Em.

FIG. 14.—The macula of an English boy, æt. thirteen, with black hair and dark-brown irides; sallow complexion. The choroidal vessels are exceptionally prominent, the interstices being filled with pigment. The curious radiating lines along the floor of the macula reaching to the foveal pit are most striking.

Compare Figs. 7 and 15. V = $\frac{6}{6}$; Emmetropic.

FIG. 15.—The macula of an Albino, pale complexion, blue irides, and white hair.

The choroidal vessels are just as prominent as in the last case, but all pigment is absent; the macula is filled with fine capillary vessels, but they are too small to be clearly defined. The fovea itself appears as an ill-defined reddish spot. From a woman, æt. twenty-one.

FIG. 16.—The macula region of a woman, æt. thirty-six, with brown hair, gray eyes, fair complexion.

The whole fundus is stippled over with black irregular-shaped specks like grains of pepper. The floor of the macula is filled with innumerable black specks, which are much finer and closer together than elsewhere. No halo could be discerned. V = $\frac{6}{6}$ nearly. I have classified this case with the healthy maculæ, although exaggerated cases may perhaps have to be considered as pathological.

Fig. 1

Fig. 2

Fig. 3.

Fig. 4.

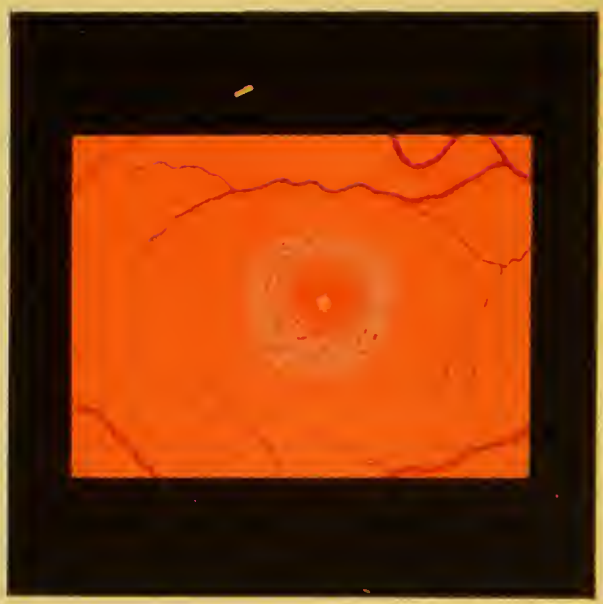

Fig 5

Fig 6

Fig 7.

Fig 8.

A.J. Abraham, lith

Fig. 9

Fig. 10

Fig. 11.

Fig. 12

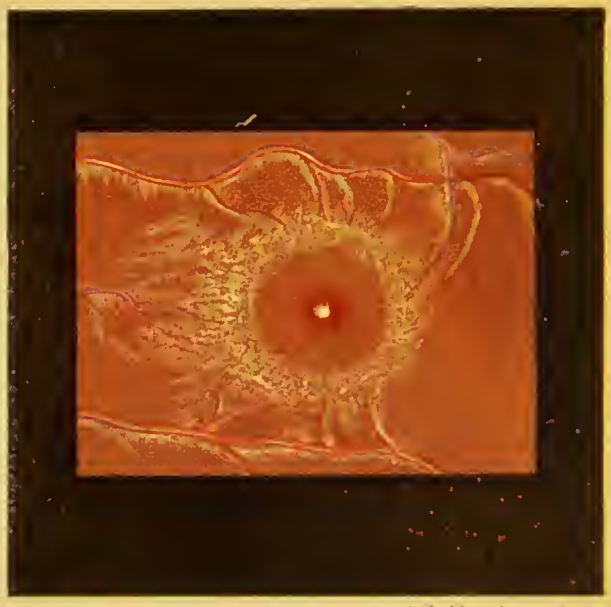

Fig. 13.

Fig. 14.

Fig. 15.

Fig. 16.